HARVARD COLLEGE OBSERVATORY
HARVARD UNIVERSITY
NASA GRANT NsG 64-60 (Supplement 1-62)

STUDY OF GROUND-BASED AND SPACE VEHICLE INFRARED INSTRUMENTATION FOR THERMAL PHOTOGRAPHY OF THE MOON, INCLUDING EXPERIMENTAL PROGRAMS AT SELECTED OBSERVATORIES

SEMIANNUAL STATUS REPORT NO. 10
1 JULY to 31 DECEMBER 1964

Project Director: Donald H. Menzel

Lunar Eclipse, December 18/19, 1964

The lunar eclipse of December 18/19, 1964 was observed from Agassiz Station, Harvard College Observatory, Harvard, Massachusetts, using our Radiation Pyrometer attached to the 61" reflector at the Newtonian focus.

Preparations were made in advance and all equipment was working with "laboratory performance." In general, observing conditions at the site were excellent. The relative humidity outside the telescope dome varied from 34% to 36% and the "seeing" was from 3 to 4 seconds of arc.

The electronic check-out started at 2:00 PM E.S.T. on December 18 followed by the astronomical program which commenced at 4:00 PM E.S.T. and continued through 2:00 AM E.S.T. on December 19. Scans were made continuously across Tycho, Copernicus, Aristarchus and the center of the disk before, during and after totality.

The detector was scanned with Alpha Orionis to determine the detector's responsivity profile and its position with respect to the reticle which determines the location of the resolution element on the lunar disk.

Toward the end of the observation at 1:00 AM E.S.T., December 19, a general mapping was made of Aristarchus, Proclus, Dionysius, Menalaus, Tycho and Copernicus.

Figure 1 shows the cooling curve for the crater Tycho and its surroundings. At the beginning of the eclipse the crater was cooler than the surroundings by 5°C and before Tycho left the umbra the crater was 35°C hotter than the surroundings.

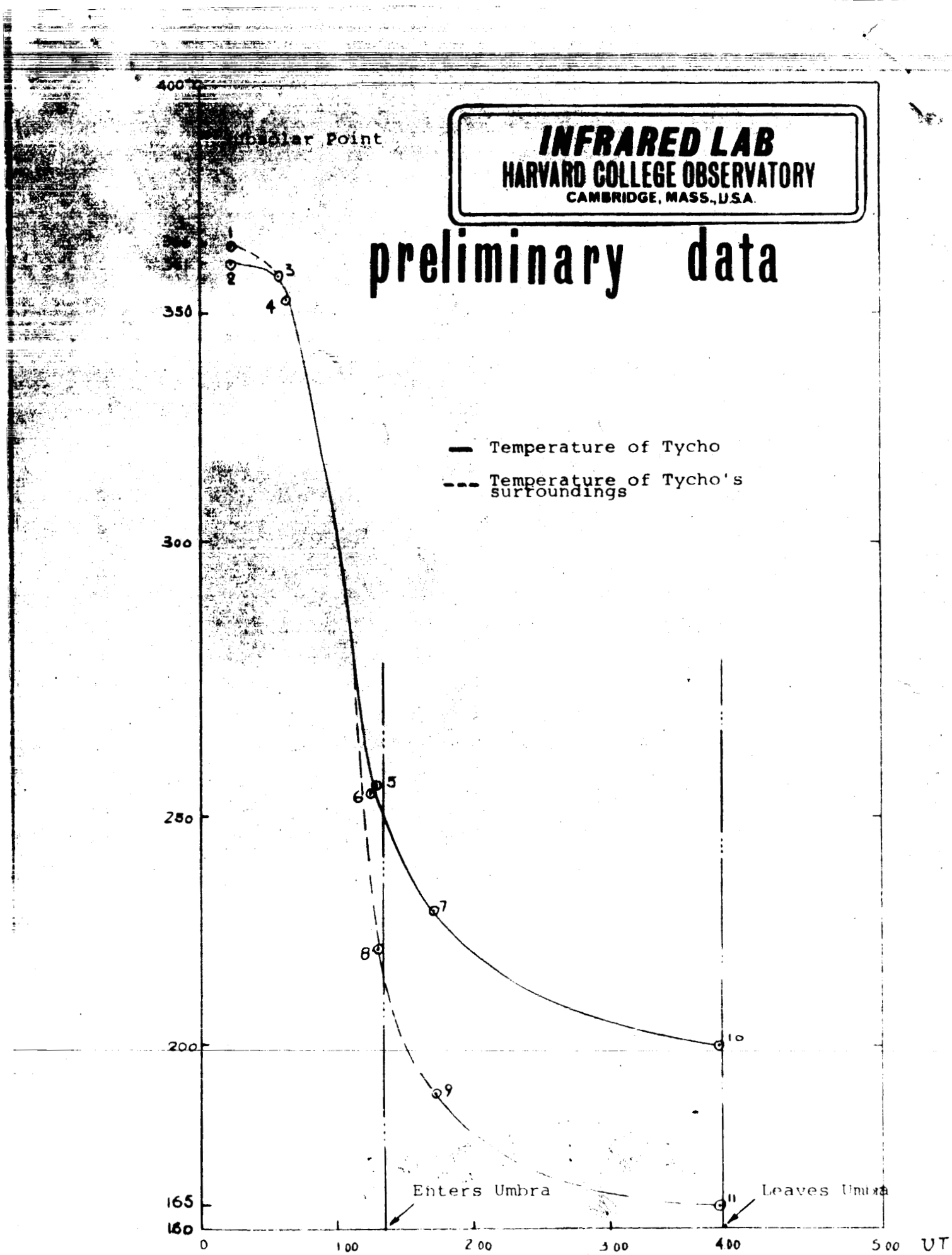

FIG. 1. Cooling curves for Tycho and surroundings during the Eclipse December 18-19, 1964.

Figure 2 shows some of the scans through Tycho. The numbers on the scan lines are the picture frames' numbers used to identify the position of the detector. The scan numbers (Nos. 1, 2, 3 & 4) are correlated with the numbers of the points in the cooling curve given in Figure 1.

Figure 3 gives the actual scan of Tycho at $01^h\ 43^m\ 36^s$ UT. The dash line is the corrected profile and the 50% power points give an approximate width of 60 seconds of arc. Tracing No. 2 is the time signals from the digital clock and tracing No. 3 is the pyrometer profile.

The data of the other craters are in the process of being reduced. The data obtained during this eclipse is very reliable; the total amount of precipitable water was in the order of 1.5mm. Furthermore, several calibrations of the equipment were secured at the beginning, middle and end of the observing.

Lunar Eclipse, June 24/25, 1964

The data of this eclipse is being punched on IBM cards, and we expect that as soon as certain difficulties in the programming are solved, the data will be immediately available.

Other Observations - Agassiz Station

Observations were scheduled at Agassiz Station in Harvard, Massachusetts commencing with November 15, 1964 through and including November 23, 1964. Unfavorable weather caused these observations to be cancelled.

Prior to and in preparation for the eclipse, observations were made on December 14/15 and on December 15/16. The infrared data are in the process of being reduced.

During these observations, Eastman plus-x pan film was used instead of the XR film used in our precious observations. The subsequent processing and printing of this film has resulted in high contrast positives which have made it easier to identify lunar features.

preliminary data

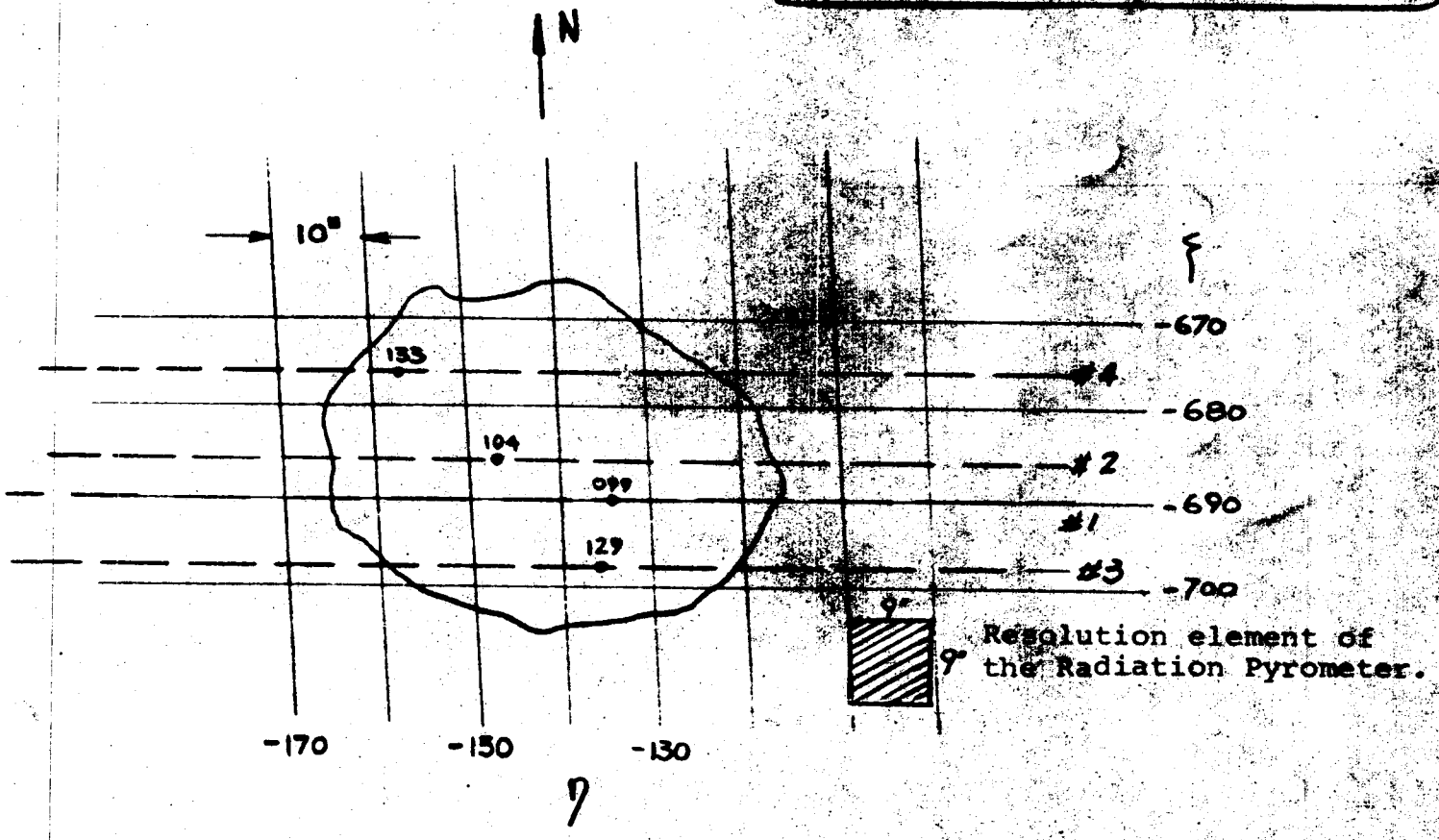

FIG. 2. Some of the scans through the crater Tycho during the Lunar Eclipse, December 18-19 (1964). The dots with numbers indicate the picture frame number for accurate identification of the position of the detector. The scan numbers are correlated with the numbers of the points in the cooling curve. The coordinates superimposed on Tycho are from the Orthographic Atlas of the Moon, The University of Arizona Press, 1960.

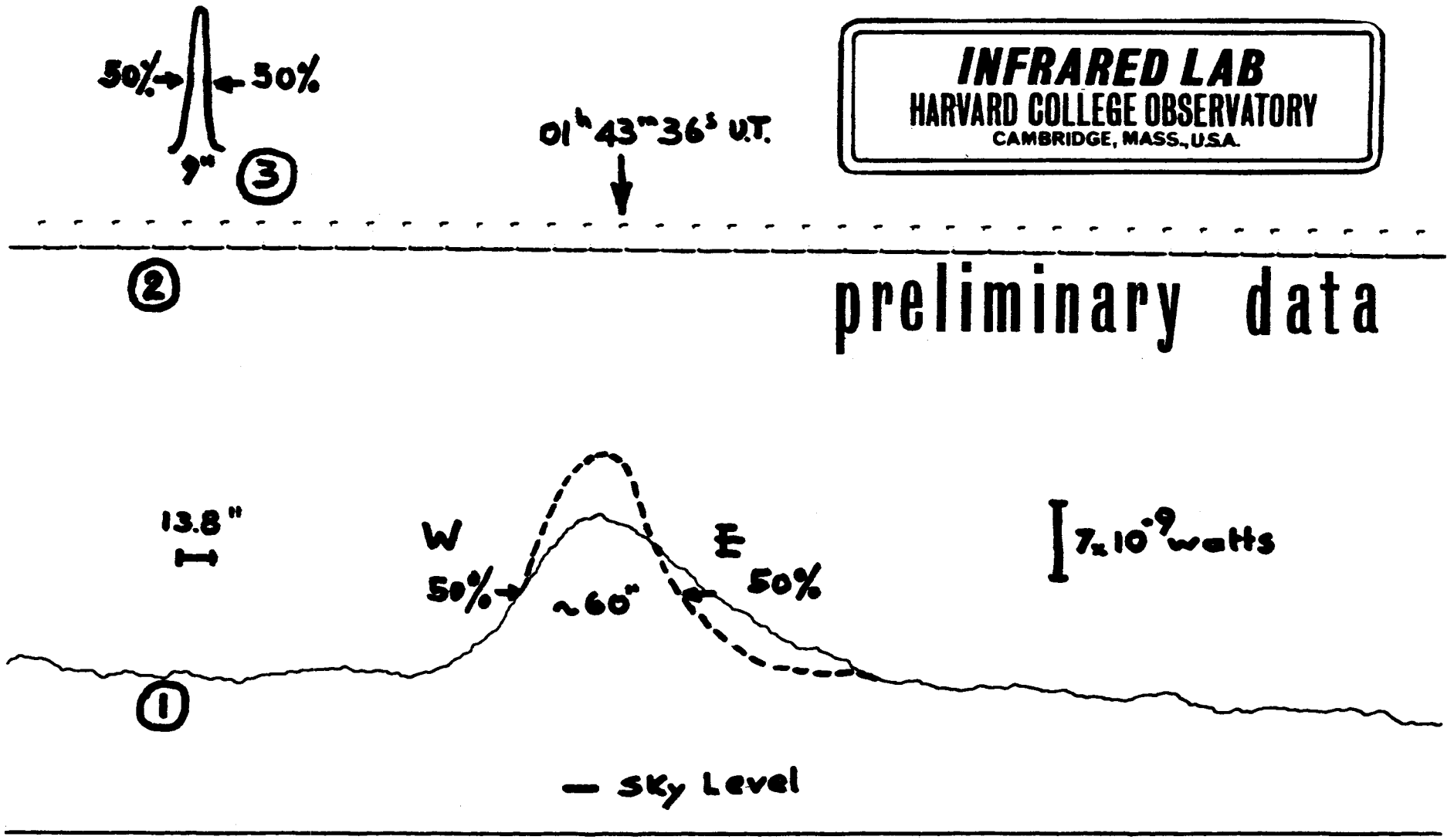

FIG. 3. 1) Scan through the crater, Tycho, at $01^h\ 43^m\ 36^s$ UT.
The dash line is the corrected scan used for the data reduction.
2) Time signals from the digital clock.
3) Instrumental profile of the Radiation Pyrometer.

Data Reduction

The Figure 4 shows the block diagram of our data processing flow. Each block is indicated by a roman numeral. The blocks from I to XVII are in operation; XVIII, XIX, XX, XXI and XXII are still to be completed.

Data Reduction - Identification of the Resolution Element on the Lunar Disk

The lunar coordinate program mentioned in the last two semiannual status reports is now in routine use. It performs the following functions:

a) Given one or more points identified photographically on a lunar scan together with the time of each photograph, the program can interpolate the lunar coordinates of the detector for any other time. In general, a uniform motion in both declination and hour angle is assumed; however, if the telescope is held stationary, this additional information can be used by the program to reduce the number of degrees of freedom and obtain greater accuracy.

b) The program will produce an ephemeris of all points along a scan passing through a specified point, for any desired time interval. Thus, the program can be used to find a point on the illuminated portion of the Moon such that a scan passing through this point will also pass through a specified feature on the dark portion. This technique allows us to map regions that cannot be seen or photographed, both during eclipses and at large phase angles.

The program has been used in both ways, and has helped considerably in planning observations. The accuracy of the calculations is on the order of 0.1 seconds of arc.

The program also provides the air mass of each point, the phase angle, and the (lunar) altitudes of both sun and observer. Thus, the geometry of each observation is completely specified. The air mass is computed with an accuracy generally better than .002; the angles are accurate to 0.1 degree except in poorly-determined geometries.

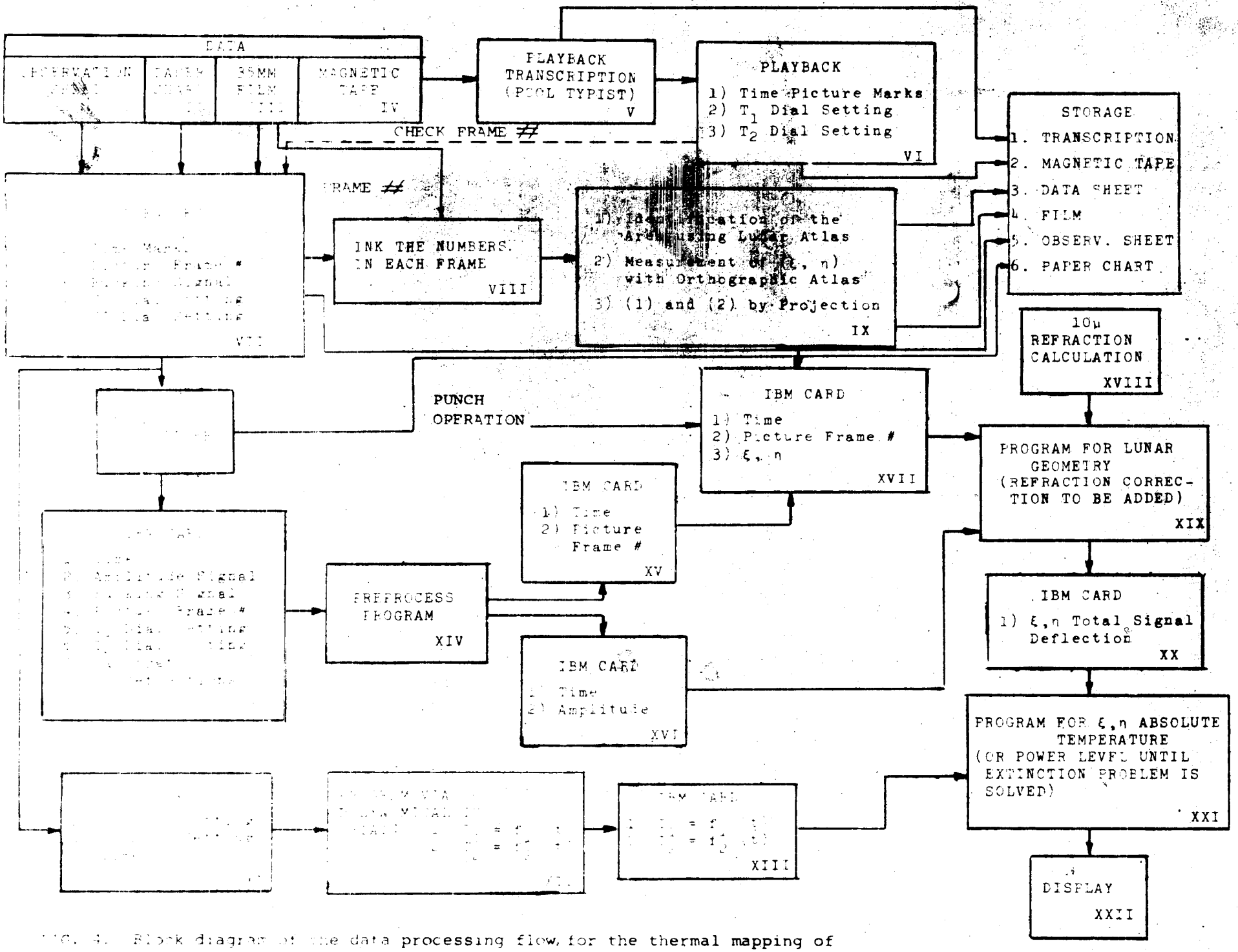

FIG. 4. Block diagram of the data processing flow, for the thermal mapping of the Moon at Harvard College Observatory.

Data Reduction - Programming

1. Formerly, the dial readings of the reference and calibration black body temperatures had to be converted graphically to degrees C or K. Dr. Young has fitted fifth-order polynomials to the calibration data and has written a short program which uses these polynomials to compute the temperatures. The accuracy of the result appears to be as good as the accuracy of the calibration data, a few hundredths of a degree. Both Celsius and Kelvin temperatures are output from the program.

The program is both easier to use and more accurate than the graphical method used formerly.

2. Dr. Young has also written a program to process the cards punched automatically via the Gerber scanner. The output from the program is in a form suitable for further processing by the coordinate program and others.

Data Reduction - Equipment

In order to further implement our data reduction program and to speed the data reduction process, the following pieces of equipment have been put into use:

1) Gerber Digital Data Reduction System Model GDDRS-3B.
2) IBM Key Punch Model 026.
3) Photo Reduction Machine.
4) Visual Record System of the Accomplished Observing.
5) Film Scanning and Marking Device.

The Gerber digitizer and the key punch are connected as a unit and can be used to produce 8000 points of data per day on IBM cards, which will be processed directly by the computer to reduce the data to indicate lunar temperatures and the orthographic coordinates of the Moon for each temperature measurement.

In order to know the precise location on the Moon's surface of the area that is under measurement and to determine its orthographic coordinates, it was necessary to develop in our laboratory a Photo Reduction Machine that will facilitate this time consuming process. This machine was designed and constructed during the current period and is now in operation.

So that our observers could readily see the status and coverage

of previous observations, a Visual Record System was installed and is now in use.

Since each film frame must be edited and numbered, the Gerber Scanner formerly used for this purpose was modified so as to make this operation easier and faster with less eye fatigue to the operator.

Since we concentrated our efforts in the processing of our data, no progress has been made during this period on the A-D Converter.

Data Reduction - Personnel

Prior to and concurrent with the installation of the equipment for data reduction, great effort was expended to obtain an experienced data analyst and an assistant to handle the processing of the data.

Mrs. Mary Leyland, astrometric computer and satellite tracker, formerly with Smithsonian Astrophysical Observatory, joined our group in October 1964 and is in charge of our data reduction. Miss Katherine Hecker started as a part time assistant for data reduction. Next January she will go on a full time basis.

We secured the services (22 hours per week) of Mrs. Elgie Levin as data analyst. She has had 5 years of experience with the MIT Computing Center and 5 years with Itek Co. Her duties will consist of inspecting the data before it is mechanically processed. Mrs. Levin will start next January.

Radiation Pyrometer

The camera mounting on the existing pyrometer head has been modified to fit the Nikon F Camera. It was found that the Nikon F Camera is less susceptible to failure than the Praktina Camera formerly used.

Increasing experience during actual observations lead us to add or improve certain parts of the electronics of the radiation pyrometer.

New Radiation Pyrometer

Most of the components required for the construction of the new pyrometer have been acquired and assembly is underway. The electronics assembly is 75% completed, and the final completion date is estimated for some time in April of 1965.

The new units are basically similar to the old ones and have been designed with the latest developments so as to approach the present "state of the art" in electronics. The pyrometer head is now being redesigned to hold quantum detectors to be cooled by liquid Helium or Hydrogen.

Atmospheric Refraction

Further evaluation of the difference in atmospheric refraction between the visible and the infrared radiation led us to drop the possibility of using the Air Force Cambridge Research Labortories program for ray tracing as we had previously considered in our Semiannual Status Report No. 9, instead we will use the Cauchy's formula.

Future Plans

Observations - To have a systematic observing program we have engaged the services of Mr. John Thorp as the Senior Observer. Mr. Thorp is with the Smithsonian Tracking Station in Jupiter, Florida and will join our group by the end of January.

We will not be able to observe the Lunar Eclipse of June 13/14, 1965 from Agassiz Station, since the air mass during the umbral phase varies from 5.6 to 3.5.

Data Reduction - Atmospheric Transmission

We are collecting data on atmospheric transmission from a variety of sources. We hope, before long, to be able to compute the "atmospheric filter function" - i.e., the atmospheric transmission as a function of wavelength - for any time, phase, and zenith angle. Then, by modifying the filter-convoluting and blackbody-radiance programs mentioned in the last Report, we shall compute

$$S(Z,T) = \int B(\lambda,T)F(\lambda)A(\lambda,Z)d\lambda$$

where B is the Planck function, F is the instrumental response function, and A is the atmospheric transmission. Then the

relation S(Z,T) will be inverted to give T(S,Z) so that an equivalent blackbody temperature can be assigned to a signal of strength S observed at zenith distance Z.

When the programs to perform these operations are completed, we will have reduced the observations to tables of temperature as a function of lunar coordinates and angles of observation and illumination.

Data Reduction

It is expected that the expansion effected in data reduction during the current reporting period will greatly speed up this phase of work during the next period. Efforts will continuously be exerted to keep data reduction moving at an increased rate.

Instrumentation

It is estimated that the second radiation pyrometer will be put into use during the first part of 1965. The A-D Converter will be started provided that all the other phases of our program, mainly data processing, are completed and smoothly under way.

Extension of Grant

A proposal and budget for a two year extension of this grant was officially submitted on January 27, 1964. During this current reporting period, the grant was extended to December 31, 1965.

Property

Major items of equipment (over $1,000.00) are being reported separately by Harvard's Office for Research Contracts.

Financial Report

The attached monthly statement for December 31, 1964 shows expenses for various categories for the closing month of this report period and cumulative expenses from the beginning of the report period.

H. C. Ingrao
Senior Research Associate
Lecturer on Astronomy

December 31, 1964

HARVARD UNIVERSITY

Office for Research Contracts

Contract NsG 64-60
Department 66-706
Account 7158

Project Director: D.H. Menzel

OPERATING STATEMENT AS OF 31 DECEMBER 1964

	December	Total to Date
Salaries and Wages	3,982.92	137,854.25
Pensions, Social Security, etc.	442.69	13,441.68
Equipment	633.87	34,006.18
Supplies	3,773.14	35,212.78
Telephone and Telegraph	5.08	2,231.30
Freight, Express and Postage	9.50	5,534.22
Travel	318.91	15,199.48
Insurance		181.66
Miscellaneous		(3.20)
Services Purchased	1,214.85	28,555.47
Computer Time	346.79	346.79
Total Direct Disbursements	10,727.75	272,560.61
Overhead 20%	2,145.55	68,701.98
Total Disbursements Including Overhead	12,873.30	341,262.59
Total Contract Funds Allocated to Date		491,504.00
Unexpended Contract Funds		151,241.41

Contract Period: January 1, 1960 to December 31, 1965

R. W. Pratt, Director

Date: 2/1/65